REMARKS

The present invention relates to manufacture of piezoelectric parts. The presence of internal electrodes within a piezoelectric ceramic body have led to the deterioration of piezoelectric properties and poor reliability when attempts have been made to reduce the size of monolithic piezoelectric parts by reducing the thickness of the layer of the ceramic sheets which make up such parts and increasing the number of sheets. One property deteriorated is the piezoelectric d constant which relates the amount of mechanical strain produced by an applied electric field. However, a high constant is required in certain monolithic piezoelectric parts such as monolithic piezoelectric actuators and audio emitters.

It is recognized in the art that when the piezoelectric ceramic is a lead perovskite type material, the piezoelectric d constant is conspicuously deteriorates when sintering takes place in a low oxygen atmosphere because that low oxygen concentration promotes the generation of oxygen pores. When the oxygen concentration is reduced to less than 1 percent by volume or when a soft piezoelectric ceramic material with a high piezoelectric d constant is used, the deterioration is so severe that it is difficult to even form the desired monolithic piezoelectric part.

The present invention is based, in part, on the discovery that a layered article having a plurality of piezoelectric ceramic layers and spaced internal electrode layers disposed in the part can be fabricated without deteriorating the piezoelectric d constant by co-sintering the ceramic layers and internal electrode layers in an atmosphere where the oxygen concentration is up to about 5 volume percent, but not zero percent, when the molar quantity of the A site of the perovskite has been reduced by about 0.5 to 5 mole percent from the stoichiometric amount, and the average valence of the B site component is increased to greater than 4 but less than 4.1. The fact that the deterioration of the constant can be combated is surprising and unexpected.

Claims 1, 4, 5, 7-9, 11 and 14-16 have also been rejected under 35 U.S.C. over Horikawa '328 in view of Ponomarev, Horikawa '408 and JP '511. This rejection is also respectfully traversed.

The Horikawa '328 reference has been cited to show co-sintering of a structure having laminated green piezoelectric ceramic and internal electrode layers. As acknowledged in the Office Action, there is no disclosure in this reference of altering the stoichiometry of the perovskite or sintering in a reduced oxygen atmosphere.

The Ponomarev reference has been cited solely to teach that low loss hard piezoelectric ceramic materials are desired in multi-layer ceramic transformers.

Horikawa '408 relates to low loss piezoelectric ceramics for high frequency filters and isolators. The ceramic has the particular composition given at column 2, lines 50 to 55 and is formed by preparing a ceramic molded body of the ceramic which is sintered and thereafter processed for the application of electrodes. There is no teaching or suggestion in this reference of cofiring a green (unsintered) piezoelectric ceramic with internal electrodes under any conditions. In addition, there is no teaching or suggestion that the ceramic should be fired in a reduced oxygen atmosphere for any reason. Accordingly, Horikawa '408 did not have to face the problem of deterioration of the d constant.

There is no suggestion in the combination of Horikawa '328, Ponomarev, and Horikawa '408 that piezoelectric parts can be fabricated without deteriorating the piezoelectric d constant, a surprising and unexpected result, by co-sintering ceramic layers and internal electrode layers in an atmosphere where the oxygen concentration is up to about 5 volume percent, but not zero percent, when the molar quantity of the A site of the perovskite has been reduced by about 0.5 to 5 mole percent from the

stoichiometric amount, and the average valence of the B site component is increased to greater than 4 but less than 4.1. JP '511 does not obviate this deficiency.

JP '511 discloses a ceramic capacitor made by sintering in a low oxygen atmosphere but the ceramic neither contains lead nor is a lead perovskite piezoelectric ceramic. The ceramic in this reference is either 97wt% TiO_2 – 2wt% CuO – 1wt% Zr (page 3) or 95wt% TiO_2 – 4wt% CuO – 1wt% Zr (page 4). The other references proposed in this combination rejection concern PZT system piezoelectric ceramics. There is no motivation to utilize something which may be applicable to the JP '511 system ceramic with the Pb PZT ceramics of the other references, nor is any proposed motivation set forth in the Office Action. It is therefore clear that the reliance on JP '511 can only be based on impermissible hindsight.

The attention of the Examiner is also invited to the discussion of the Japanese Patent which issued based on the application JP '511, namely Japanese Patent No. 2,676,620, on pages 2-3 of the present specification.

Moreover, the art already of record must also be taken into consideration. In this connection, the Randall reference teaches co-firing multi-layered piezoelectric ceramic materials with base metal electrodes and acknowledges that there are significant problems with such co-firing, including, *inter alia,* firing without oxidation of the electrodes and also without reduction of the PZT or other ceramic material. See e.g. paragraph [0007]. The prior art discussed on page 2 of the application teaches the skilled person that piezoelectric transformer made with hard type ceramic and silver electrodes achieved good properties by increasing the A site perovskite component. It also teaches the artisan that sintering a lead perovskite piezoelectric ceramic material in a reduced oxygen atmosphere to suppress silver dispersion in the ceramic lead to significant deterioration in the piezoelectric d constant by generating oxygen pores to

an extent which could even render the sintered ceramic unusable for its intended purpose. This fact is further illustrated in the comparative examples of Table 3 in the present application.

The record in this case clearly establishes that those skilled in the art would expect a lead perovskite piezoelectric ceramic material to have a deteriorated piezoelectric d constant if sintered in a reduced oxygen atmosphere. The fact that the deterioration can be combated when making an actuator or emitter by employing a ceramic whose A and B site stoichiometric amounts have been altered as claimed is not taught or suggested and is surprising and unexpected.

Claims 6 and 21 were rejected under 35 U.S.C. § 103 over the same combination of references in further combination with Feltz. This additional reference has been cited only to teach that it is possible to do partial substitution of the ions in the B position of the perovskite but not to show how to overcome the deficiencies in the prior combinations of references discussed above. Accordingly, the further combination of these references with Feltz cannot render the invention obvious.

Claims 12 and 13 were rejected under 35 U.S.C. 103 over the references applied to claim 11 and in further combination with JP '035. The additional Japanese reference has been cited only with regard to the internal electrodes and not to overcome the basic deficiencies in the base combination of references. It does not do so and withdrawal of this rejection is respectfully solicited.

Claims 22 – 26 were rejected under 35 U.S.C. 103 over the references applied to claim 1 and in further combination with Ogawa or Takeshima. These additional references show that a buzzer could be a type of piezoelectric device. Such a teaching

does not cure the basic deficiencies in the base combination of references, and cannot serve to render these claims obvious.

In light of all of the foregoing, it is respectfully submitted that this application is now in condition to be allowed and the early issuance of a Notice of Allowance is respectfully requested.

Dated: May 18, 2006

Respectfully submitted,

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